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HoloLearning - Education Application for Engineering Students using Mixed Reality

[1]Rishika Godgul, [2]Akshay Bhat, [3]Asawari Paste, [4]Harshal Tathe, [5]Prof. S.B. Shinde

[1,2,3,4,5] *Department of computer Engineering, Modern Education Society's College of Engineering, Pune, Maharashtra.*

ABSTRACT

Virtual and Mixed Reality technologies have evolved because of increasing digitisation and advancements in technologies, the aspects of which will help us make reforms in the 21st century. There are several researches and studies which show us that virtual and mixed realty elements have motivated the students positively towards learning processes, thus making the technologies more popular in the field of education. Mixed Reality (MR) is poised to revolutionise education by immersing students in learning experiences in a way no other technology has before.

MR technology is used in the field of education as it allows us to interact with both physical and virtual objects efficiently. Various features of MR help the professors to explain abstract concepts in a more suggestive and interesting manner, also VR helps to make the students' study experience more interactive, effective and exciting by allowing more realistic experiences, thus promoting maximum understanding of complicated concepts. Our paper summarises the execution of a synergistic learning application using the Mixed Reality device -Microsoft HoloLens which enables us to interact spatially with synthetically generated 3D-holographic objects.

Keywords — Mixed Reality, Augmented Reality, Virtual Reality, Microsoft HoloLens, 3D-Holograms

1. INTRODUCTION

Since few years, universities have introduced computing courses which help students enhance their computational thinking skills by encouraging them to develop several computer programs for solving various problems creatively.

The use of mobile devices, computers and other emerging technologies have become ubiquitous across the university curriculums; therefore, the universities are promoting students to develop and innovate by teaching digital skills using upcoming technologies.

Several tasks like creating visualisations, analysing data, performing simulations, navigating online content, etc. are assigned to the students to understand and experience various underlying computing concepts. As the saying goes "Big surprises come in small packets", smaller the size of the hardware in the form of head-mounted devices, it will get more powerful and efficient and will be highly capable in terms of wearable devices.

Several applications of Mixed Reality as well as Virtual Reality have already been discussed widely in several sections of the working world. More and more developments and innovations are expected to occur in the future.

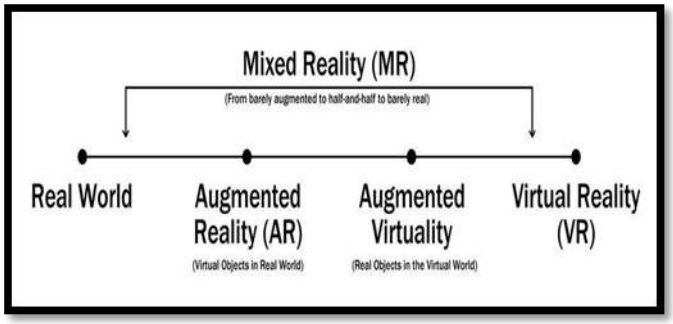

Figure 1: - Mixed Reality spectrum

As mixed reality is the blending of the physical world and digital world, these two realities define the polar ends of a spectrum known as the vitality continuum. For simplicity, it is referred to as the *mixed reality spectrum* as depicted in Figure 1. On the left-hand side we have physical reality in which we, humans, exist. Then on the right-hand side we have the corresponding digital reality.
Let us briefly see what each of these aspects involves: -

1.1 Augmented Reality

Augmented reality (AR), is a technology that enhances your perception and visualisation of the real world by superimposing virtual objects onto the real environment.
Basic Characteristics of Augmented reality (AR) are listed as –
1. Overlay of Real and Digital world
2. Real-time interaction
3. Registration and Alignment in 3D

Augmented Reality transforms the surroundings using overlay imagery and thus brings non-existent objects into the real world. It is used in a wide variety of fields like education, arts, marketing, military, media, and business.

Augmented reality in education will soon revolutionise the conventional learning process. AR has the potential to change the location and timing of studying, to introduce new and additional ways and methods. Capabilities of Augmented Reality technology may make classes more engaging and information more apprehend able.

Educators know that the learning process should be all about creativity and interaction. While teachers do not necessarily need to recruit all students into science, their goal is to get them interested in a subject. That's where AR could come in handy.

Many AR devices available in the market are Meta 2, Google glasses, Optinvent ora-2, etc. which are being profoundly used by educators and various developers to build and test various AR applications.

1.2 Virtual Reality

Virtual Reality (VR) on the other hand makes use of computer technology to create a simulated environment. Unlike traditional user interfaces, VR places the user inside an experience. Instead of viewing a screen in front of them, users are immersed and able to interact with 3D worlds. By simulating as many senses as possible, such as vision, hearing and touch the computer is transformed into a sentinel to this artificial world. Virtual reality takes you away from the real world and completely blocks your sight with another digital environment. It is being used in various fields like architecture, tourism, rehabilitation, healthcare, sports, and entertainment.

The main goal of Virtual Reality in education is to make learning process exciting and more effective. VR simulations provide a deep understanding of the material by a learner with its further application in real life. The strongest proof that virtual reality and Mixed Reality can make good for the education system is in the way the human brain has been wired. The fact is that the brain tends to remember 10% of what it reads, 20% of what it hears, and 90% of what it does or simulates. Therefore, VR can contribute in maximum percentage to help synthesise information faster and retain for longer.

Various VR devices which applications are being built include HTC Vive, Oculus rift, Google cardboard, etc.

1.3 Mixed Reality

Mixed Reality combines best aspects of AR and VR by bringing virtual images in real time and space, helps to visualize them, and makes them appear as good as real ones thanks to the advanced algorithms of coordinate calculation.

Mixed reality devices have a head-mounted display which allows us to experience a more interactive environment as they are capable of overlaying 3D content onto the physical surroundings.
Various existing MR devices are primarily driven by hand gestures, gaze and voice commands. Recently, most of the developments made in the domain of MR are focussing on the implementations in the fields of health, education, business management, automobiles, machinery, etc.

By including MR in higher education, universities provide students the opportunity to experience theoretical concepts and encounter the latest technologies. The 3D holographic images enhance the way concepts are delivered, it creates an aura around the students which builds interest and grasps their focussed attention for a more foreseeably longer amount of time.

It is basically more advisable because it provides better visualisation and helps them to practice and rehearse situations which wouldn't be practically possible in real-time. Student presents themselves more actively and grasp the concepts faster. This becomes an advantage when the students want to design their own systems and applications.

There are two main types of devices that efficiently deliver the Windows Mixed Reality experiences. These devices involve: -

1. Holographic devices – example: Microsoft HoloLens
2. Immersive devices – example: Acer Windows Mixed Reality Edition

Thus, by studying all the realities and various devices, we have accounted the usability's of each of them and used it in the development of our project. Curating an application which not only involves help for the students but also makes delivering lectures for teachers more empowering and technologically advanced.

2. LITERATURE REVIEW

We surveyed our domain on basis of two aspects- 1. Studying the applications and uses of MR, VR, and AR in education, 2. Surveying various devices developed using MR, VR, AR Augmented reality keeps students engaged in their work and makes them understand better using 3D visuals, it motivates them in learning new things, and students learning with AR technology give better results. Method of learning has been changing from past years from traditional methods of learning such as text books to widely used digital tools present for students in institutes to make information accessible and interactive, now students are not using only the brain but the whole body to interact with tools to learn, which is increasing their interest in learning. Students use their body to control virtual objects while they study. The Redmond, Washington-based company utilized HoloLens in different environments to monitor its effect in learning. Students found it beneficial while learning different challenging materials. NASA is using Microsoft HoloLens in their project Sidekick for training the astronauts aboard the International Space Station.

Through field research, educators and students seemingly agreed on the benefits that the mixed reality headset brought to their learning environment. The HoloLens allowed students to engage hands-on in their subjects to reach new dimensions of understanding. Making challenging topics for students young and old accessible by creating a more visual and tactile experience. [1]

This technology does not depend on single field of study, many completely different fields are using this technology to make their trainees or students learn efficiently, first application related to HoloLens was created by EdTech innovation team from Leiden University for medical students, in which holograms in the application moves with your body, help to study the anatomy and about movements of various body parts like ankles. [2][3]

An advantage of working with HoloLens simulation is that there is no harm if something goes wrong. Another completely different field which is using Microsoft HoloLens is developing engines for motor vehicles. In which even nonprogrammer can design and monitor their engine. Even though you won't have real product to test but the technology allows you to see your product in 3D and makes you visualize how it will look when developed.

S. Howard, K. Sarpanch, and K. Lewin developed an application for including virtual reality content for higher education. It was done by forming a partnership between Queensland University of Technology (QUT) Library and ProQuest which facilitated a unique opportunity to work together to establish a research project to explore high quality Virtual Reality content delivery options that would contribute to enhancing information resources for libraries and their clients. The goals of the project included providing Virtual Reality content and resources at QUT to enhance the student experience through the engagement of technology; identifying the need within Faculty for the use of Virtual Reality content and resources (and subsequently provide additional options for blended learning resources); and developing and enhancing the capabilities and awareness of university staff and students within the area of Virtual Reality. [4]

A study performed by Willicks, Freya, et al., to gather information about the students' perception of Mixed Reality in higher education. It showed that younger students have stronger requirements for Mixed Reality in higher education. They prepared questions such as what does students associate with the term "Mixed Reality"? What is the students' general attitude toward the use of Mixed Reality in higher education? etc. [6]

Clement Onie, James Hamish, Roger Austin, Victor McNair, in 2017 presented their study of several smart (mixed reality) technologies and applications for learning in Engineering education and discussed some issues such as knowledge integration and virtual experimentation in the context of applying smart technologies for visualisation in higher science and engineering education along with results from a study carried out at two academic institutions. The contributions of their paper included a measurable cost-effective use of smart

technologies and applications for visualisation based on adequate learning theories, styles and approaches with knowledge integration suitable for engineering disciplines also in developing countries. [7]

The works of Vinh T. Nguyen and Tommy dang aimed towards building a computational thinking game application having a comprehensive framework built using VR and AR; each component of the application was integrated using Unity game engine and they also addressed the typical challenges they faced while building the application. Their proposed framework works as a guideline to help students and instructors in various fields to build and construct their own material and application. [8]

Agate Lis-Marciniak, Jan Romanowski and Pawed Kapustka discussed the design rules, implementations and testing of User Interfaces for Mixed Reality Applications. In their article they showed how important it is to test innovative functionalities early in development phase as it might not be what end-users expect. The study was based on game prepared for Mixed Reality Platform. [9]

Milena Duntsch, Denise Stamata, Marin B. Marino, studied the applications of MR smart glasses for interactive working where the use of HMD of Microsoft HoloLens enables spatial interaction with synthetically generated 3D objects. 3D manipulations, such as positioning, scaling and rotating are also a part of its functionality. The application discussed by them worked with 3D rigid objects that physically behave properly within the VR environment. Their study also discusses the methods used to build a user-friendly application and the main steps for its creation. [10]

Oleksy, T. and A. Wnuk examined how playing a game employing augmented reality (AR) technology increases attachment to the place of playing. Place attachment refers to the relationship between people and places, which has numerous benefits for individual well-being. Their analyses showed that satisfaction from playing and the social relations made during play positively predict place attachment, but the amount of time spent on playing does not. A series of mediation analyses showed that relations among game satisfaction, social relations, and place attachment were mediated by the appraisal of the place as exciting. Their study demonstrated a mechanism of emotional transfer between positive experiences from playing and place attachment, which may prove useful in other domains, such as education, land conservation, or marketing. [11]

Matsutomo, S., et al. proposed a system which provides observation of a magnetic field distribution and its stereoscopic vision in 3-D space using head mounted display. To improve the visualization capabilities, a new real-time method for drawing magnetic flux lines in 3-D space is developed and presented in this paper. It enables a user to easily observe and grasp a magnetic field generated by multiple sources (e.g., magnets and/or multiple coils) in an augmented 3-D space. Additionally, it permits a user to freely and interactively move the magnetic sources within the visualization space and to observe the magnetic fields interference in real-time. As a result, one can intuitively and easy visualize, observe and grasp the magnetic field even in 3-D space. [12]

Madhav Murthy, et al. developed an AR tool which has proven to be an affordable, effective and immersive way to teach engineering drawing course. All engineering students undergo a complete course on engineering drawing where orthographic projections are taught. In orthographic projections, the students are asked to imagine a 3D situation and make the 2D orthographic projection drawing. This part of 3D imagination and converting it into orthographic projection is difficult for students to mentally visualize. To ease the student's imagination, An Augmented Reality solution is developed jointly by BMSCE and Bosch (RBEI), Bangalore. A powerful 3D graphics association has been developed which forms the primary source of developing the drawing as orthographic projections that is viewable in 3D in real world. [13]

Ghulamani, Sumbul & Zareen, Shafaque proposed a new method of education with the help of AR technology for the students in remote areas, to whom proper education is not provided. Students wearing AR glasses would be able to attend lectures recorded from teachers a far distance, with view as if teacher is present at that moment. Students can be grouped together to see same lectures and discuss with each other. Teachers from various places can also give live lectures to different group of students with AR glasses and give them answers to their questions. [14]

Wei, X., Weng, D., Liu, Y., & Wang, Y. presented a general technical creative design teaching scheme that includes AR. Their approach is based on the ARCS model of motivational design, social psychology, and a computational model of creativity. Two teaching aids are introduced to support this teaching scheme: "AR Creative-Classroom," which explains the domain-relevant knowledge of creative design, and "AR Creative-Builder," which helps students to build actual AR scenes. The results of a pilot study show that the proposed teaching scheme significantly improves learning motivation, student creativity, and the teaching of creative design. [15]

Rezende, W.J. et al presented a mobile software educational tool for children, using the Jigsaw methodology and augmented reality (AR) technology, aiming to improve teaching experience. The proposed software contains an AR marker reader, a game library and a digital quiz module. By presenting book contents

in three dimensions, together with the use of Jigsaw learning, we create an interactive and fun environment for learning that can help increase the interest and motivation of students. [16]

Inspiring applications and devices have been developed and upgraded through the years being a motivation to look forward in the field of mixed reality. In 1957, a virtual reality machine, called Sensorama was developed by one famous cinematographer, named Morton Leonard Heilig. He was known as "Father of Virtual Reality". Sensorama can be described as a movie theatre with one seat, enabling the user to feel and act as if he/she was actually being in the movie.

In 1968, Ivan Sutherland created the first Head Mounted Display (HMD) system. It was named as "The Sword of Damocles". This HMD had very limited capabilities. But this invention was the first step towards the development of AR. While, the term Augmented reality was first used by Tom Caudell in 1990, the door to AR was opened into the consumer world by Hirokazu Kato with the release of AR Toolkit in 1999. AR Toolkit is an open source library. It allows a developer to develop AR applications. By using this, any Smartphone having a camera and internet connection can capture video in the real world while superimposing 3D images on it.

In 2008, development of AR based applications for Smartphone has been started by mobile app developers. This has been just a start in terms of recognizing AR globally.

In 2011, Google engineered a prototype of smaller and slimmer version of HMD, named Google Glass. Initially, it weighed about 3.6 kg. In April 2012, Google has publicly announced the Explorer edition of Google Glass, weighing about 36 gm. Later in April 2013, this was made available to developers. Google Glass was a really very innovative and inspirational approach in the field of development of AR. But the user could not have interaction between virtual information (graphics) and the real world. The limitation of only displaying information, rather than the interaction between virtual and the real world, one of the "Three Basic Characteristics of AR" made it disqualified for the AR field. The Google Glass Explorer program had ended by Google in January 2015.

In January 2015, a project similar to Google Glass, a wearable HMD, named as Microsoft HoloLens was released by Microsoft. However, unlike Google Glass, it has an ability to simulate interactive holograms in the user's view of sight using AR. This makes Microsoft HoloLens fits into the AR qualification criteria.
Further recently in February 2019, Microsoft HoloLens-2 was released which highlighted three main improvements made to the device: immersiveness, ergonomics and business friendliness. HoloLens 2 has a diagonal field of view of 52°, improving over the 34° field of view of the first edition of HoloLens, while keeping a resolution of 47 pixels per degree.

3. TECHNOLOGY & METHODOLOGY

3.1 Microsoft HoloLens

The HoloLens uses see-through lenses and two light engines to project the augmented content. It automatically calibrates pupillary distance, has a "holographic resolution" of 2.3 M total light points and a "holographic density" of more than 2.5 k light points per radian. In order to scan the environment, it uses four dedicated cameras, in addition to the depth camera and the 2 MP photo/video camera. It also has an inertial measurement unit (IMU) for head movements tracking, an ambient light sensor, a spatial sound system and four microphones.

Figure 2: - Microsoft HoloLens

For sensors data processing and camera feeds, Microsoft created a custom chip, the so-called Holographic Processing Unit (HPU). More information on the device can be found in. HPU generates a 3-D model of the surrounding environment. This model can then be used from Apps for positioning holograms without reducing the processing ability of the Atom processor on sensor data handling. As a Windows 10 device, HoloLens can run most 32-bit-processor-compatible Windows Universal Platform apps. Non-holographic applications run as floating virtual screens that you place in your environment. Some of the main limitations of HoloLens are its short view field and its size, which can be overcome in the future through enhanced technology.

3.2 Unity Game Engine and Visual Studio

For our application, we have used the Unity game Engine. The procedure for building an application to be deployed on the Microsoft HoloLens is very specific. Standard game platforms are targeted for simple compilation in the Unity editor, but while building an application for HoloLens we need to introduce an additional step wherein the Unity engine creates an intermediary Visual Studio solution. The compilation of this solution then takes place in visual studio platform. Thus, for developing this application we make use of two different compilers. The application designed helps to observe mixed reality environment and allows students to actively interact with the synthetically designed 3D holographic objects and also allows the 3D objects to physically interact with each other.

4. PROPOSED SYSTEM

The deployment process of this application primarily consists of three parts. The first is the use of HoloLens Toolkit which is used by the developer and is a platform that aids the developer to work with various functionalities of the HoloLens. Scripts make up the most important aspect of the application as they contain the functionalities, thus for the second part of implementation. The third part involves creation of 3D models which are created with the help of 3D modelling tools and then transferred to the Unity Engine which is further made available on the device as a 3D-holographic object.
The following Fig.3 shows the various individual parts and how they contribute to the system.

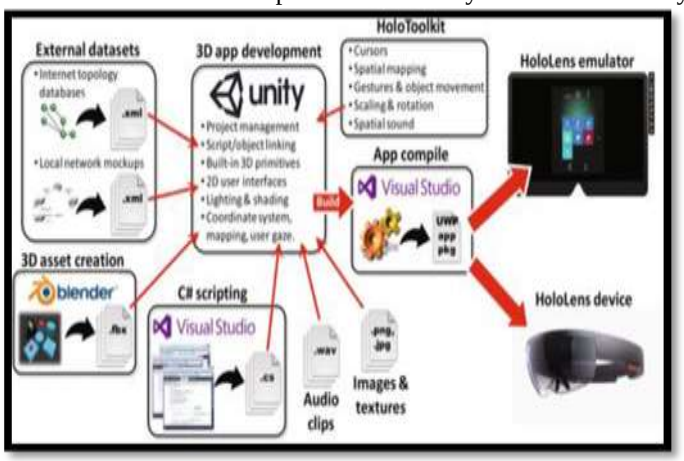

Figure 3: - Basic components for system Implementation

4.1 HoloLens -Toolkit

The HoloLens toolkit is an important component of Mixed Reality Toolkit which allows us to develop several applications in the Unity Environment. It is necessary for the toolkit to be enables on the headset in order to allow the developer to access its functionalities.

An example of the functionality used in designing our application is the *MixedRealityCameraParent*-Prefab. It helps us in replacing the frequently used Main Camera and presents to us what the user can see through the HoloLens. Also, in order to enable the HoloLens cursor, we make use of the Prefab "*DefaultCursor*" which is present in the HoloLens toolkit. It is also possible to generate and use our own functionalities via script. For example, the *InputHandler* from the HoloLens-Toolkit/Input/Script is used, which helps us handle the HoloLens-air tap gestures. Only then is the clone object of the selected 3D object is created and generates further views.

4.2 Scripts

Several scripts have been developed and used in this project. The script "Buttons" was used in the application designed for displaying linked list. This script was used in the link list application. The script is first added to an empty GameObject then the Prefabs are dropped inside them. The prefabs in this case were the Cube along with the Link. This script creates as well as destroys the links dynamically. The Linked list application uses only this single script.

The buttons are activated as soon as we make use of the air tap gesture which acts as a cursor to select the objects. Air tap gesture is shown in Fig.4.

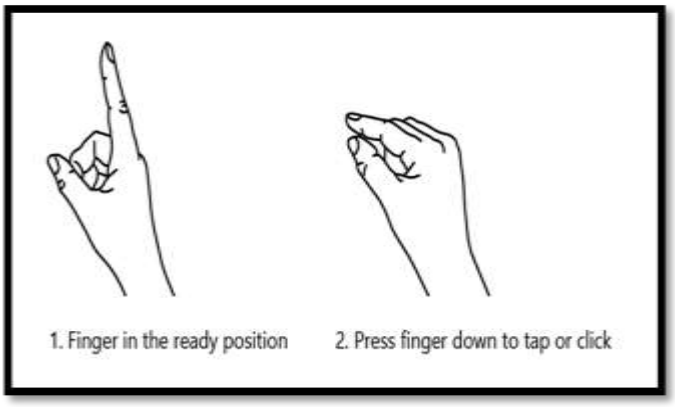

Figure 4: - Air Tap Gesture

The "CSVReader" script is used in the ScatterPlot application. This script is used for reading the csv file that we wish to plot graphically. The definition of each line is given in the code itself.

The "Dataplotter" script is also used in the ScatterPlot application. This script instantiates a GameObject and repeatedly generates it for each individual point on the graph. These help us exhibit the data mining and machine learning tasks graphically.

4.3 3D-Models

We made use of Computer animation systems to create the 3D models, which can be further used to manipulate objects like guiding the ball from start to the target point.

Further, to incorporate these 3D models into Unity by adding it in the Project Assets folder which is referred as Prefabs.

In the beginning itself, the user must be set in Unity scene so that users can interact with various parts of the project.

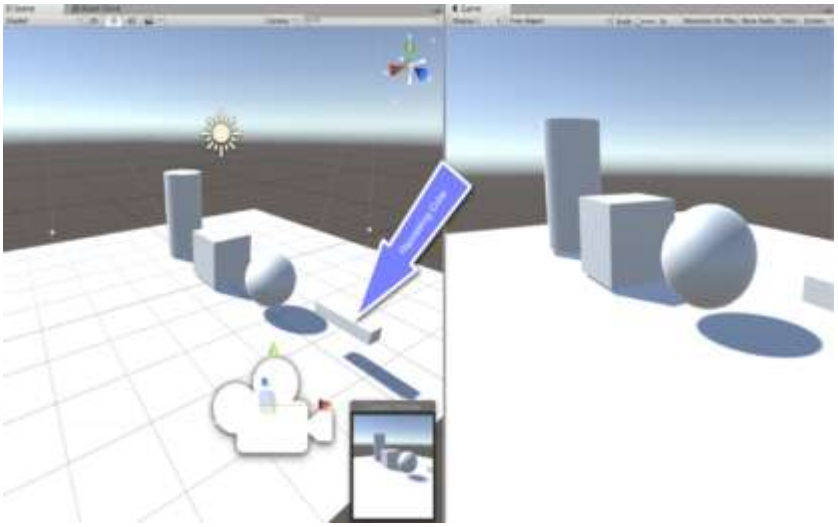

Figure 5: - 3D models in Unity Scene

5. EXPERIMENTAL RESULTS

Our application allows for an interactive way of working in HoloLens environment by providing free positioning of 3D objects in 3D space. The students can view and create 3D-Model. They can interact and see the flow of programs which will promote better understanding.

Our first module depicted the Modern Periodic table which can be views in linear, circular and tabular structures. Gazing and clicking each of the elements help the students discover and learn about the element and also know its specifications in the form of its atomic number, atomic weight, etc. The module can be seen as show in figure 6, 7 and 8.

Figure 6: - Modern Periodic table- Linear view

Figure 7: - Modern Periodic Table- Circular view

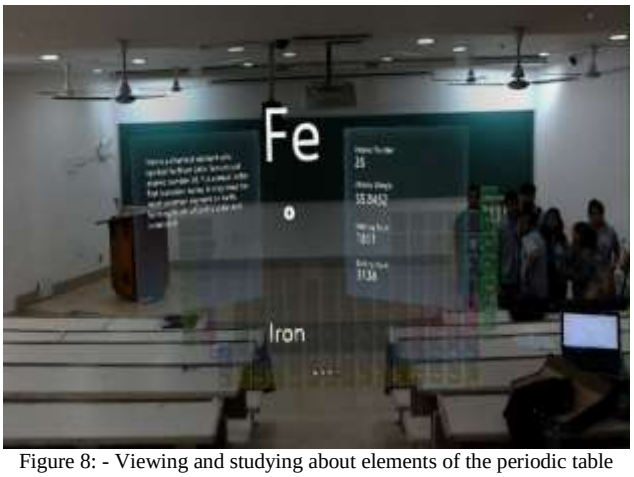

Figure 8: - Viewing and studying about elements of the periodic table

Further we implemented a module of linked list. Linked lists are one of the general foundations for Data Structures and algorithms in Computer Science. Students thus struggle to understand these complex concepts and tend to easily give up. In order to make it understandable and effortless, visualisation of linked list concepts in the form of 3D-holograms can be helpful.

The data structure module is deigned in way that the students can see the flow of program alongside the actual program code. It helps and impacts the students in learning and procuring better. Students can further generate their own codes and implement them and make programming fun. This module has various function like creation, insertion, deletion of nodes, etc. Students can have hands-on experience for each aspect of the program. The linked list module is depicted in figure 9.

Figure 9: - Depiction of the linked list along with the program code

The scatter plot viewer module helps students learn data analytics and mining tasks efficiently. The tasks also help in drawing results for several machine learning applications. Through the scatter plots we can analyse several datasets and render them in holographic form. This are most effective useful for drawing out results for large datasets. Students can learn and understand better by testing several datasets and concurrently visualising changes in the plots. The scatter plot application can be seen in Figure 10.

Figure 10: - Scatter plots used for data mining

Thus, the application can be procured as a self-learning as well a classroom based interactive applications. All the lectures can be recorded and viewed according to the students' needs and convenience. Also, the live streaming of these applications can enhance the performance.

6. CONCLUSION

Mixed Reality and Virtual Reality have various benefits for the professors of higher educational institutions. These technologies not only motivate the learners to intensify their acquisition of knowledge but also help them practice and experience various situations which would be difficult in real-life. Several studies have been carried out informing us about the various benefits procured by the teachers and trainers, so in this project we have designed the application by investigation upon the students' views for using Mixed Reality in Higher Education. We surveyed amongst the students of various engineering streams and gathered information about the topics they found difficult to grasp and register and designed our application to cater to their needs and provide equivalent solutions for their problems.

Also, the survey showed us that the students' knowledge of this technology was very little and they were mostly unaware of various advancements of MR. Nevertheless, we would want to reach out to them and spread knowledge of the characteristic attributes of MR. After receiving response from the students about the application, we concluded that integrating MR in higher education would be a great boon and students would highly appreciate this technology and also would look forward to work on the device. The students' attraction is basically because of the innovative character of the device and large horizon of opportunities that the domain of MR offers.

Professors and institution leaders who implement the HoloLearning application appropriately and technically well can lead the way to bring technologically sound reform in methods of teaching in the 21st century. Also, there is a lot of work yet to be done for making the application more desirable, reliable and safe for higher level teaching. To achieve a didactically meaningful implementation. Various technologies need to be integrated and repeatedly tested to obtain even more sound results.

In conclusion, we can say that we have achieved and built the basic framework which can be further developed into a more concrete application. Although, this application is very useful and will surely help the students improve their learning abilities.

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